**Experiment FOUR: Somatotopy**

**OVERVIEW**

**In this lab you will:**

1. learn about the way that the nervous system organizes somatotopic input from peripheral sensory structures;
2. observe the selectivity of neural responses based upon the specifics of the recording locations; and
3. investigate some basic principles on the somatotopic organization of the cockroach leg, nerves and ganglia.

**OBJECTIVES**

**Before doing this lab you should:**

* study how output sensory structures, peripheral nerves, and the spinal cord convey sensory information to the brain
* study the primary somatosensory cortex and how the brain uses these structures to interact with the outside world
* note analogies between the neural mechanisms for sensation and motor function (i.e. finger, nerve, spinal cord, brain, back down) and more simple mechanical systems such as an alarm (i.e. laser beam, wire, relay, computer, chime)

**After doing this lab you should be able to:**

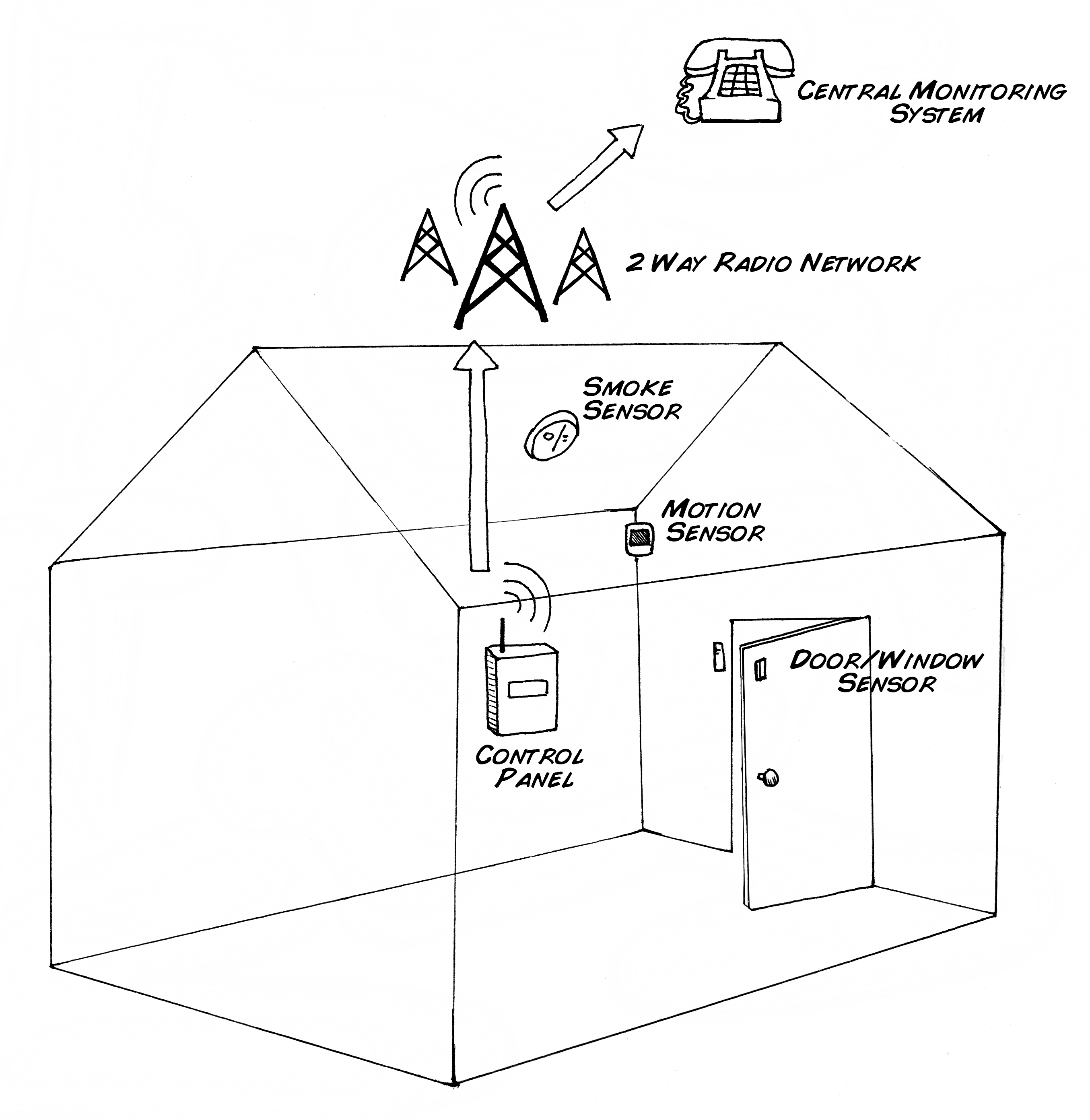
* explain why manipulating one sensory barb on the cockroach leads to a different neural response than manipulating at a different location
* design an experiment to map out which central nervous system ganglia convey information from which sensory barbs on a cockroach leg
* describe what a somatotopic arrangement means to the study of sensory deficit pathologies (i.e. blindness, deafness, paralysis, etc.)

**EQUIPMENT**

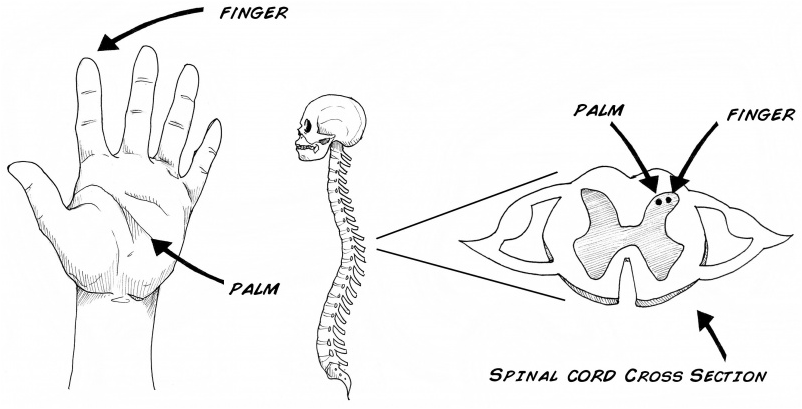
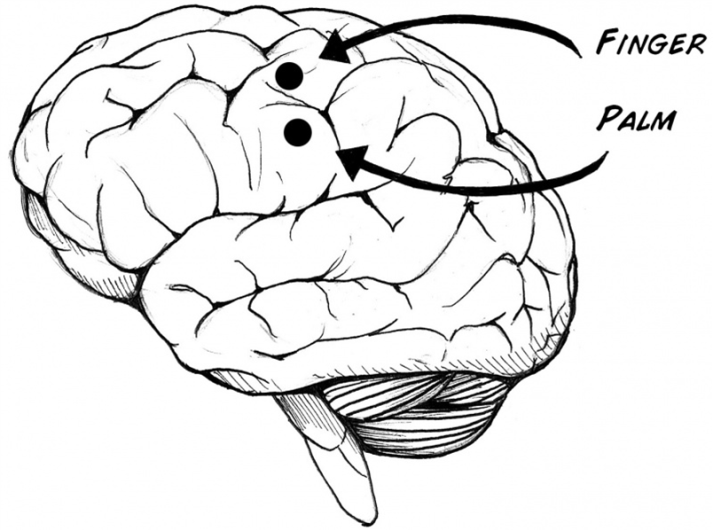
* SpikerBox
* Computer with Audacity installed or iPhone/iPad/Android with Backyard Brains app
* Associated laptop cable or iPhone/Android cable
* Cockroach
* Dissection scissors
* Toothpick

**INTRODUCTION**

The human brain recognizes sensory cues and initiates complicated sets of motor behaviors in ways that no current computer can come close to replicating, making every sight or touch that we experience and every voluntary action we take a masterpiece of engineering. The “touch” system in people is governed by the **somatosensory system** and, much like human-engineered devices, it is the hardware and wiring comprising the system that allows us to perceive pressure. Thus, understanding the organs and connections that comprise the somatosensory system is the key to understanding how we interface with the world.

Before we move on to the more complicated and intricate biological somatosensory system, let’s first look at a simpler example of human engineering: the alarm. A home alarm system might have multiple ways to detect an intruder. Contact sensors on the doors or windows maintain a closed circuit for as long as the two sensor plates are connected, but when someone opens the door the circuit is broken, that signal is relayed and travels down a connection to a central decision-making location. Similarly, motion detectors can take advantage of simple radar, sonar, or laser beams to detect when a moving entity is in the room. More complicated systems might be able to detect changes in room temperature due to body heat, or sounds made in what should be quiet areas. But all of these ways to “sense” the presence of a person require some type of external sensing device that, when activated, communicates its findings to some sort of relay that has a Boolean “on” (something is detected) or “off” (nothing has changed) setting. When the relay is activated, it reports its findings through a wire or (these days) wireless connection to some sort of computer processor that then decides how to react (e.g. warning chime, full alarm, place call to the police, etc.) based upon its programmed parameters.

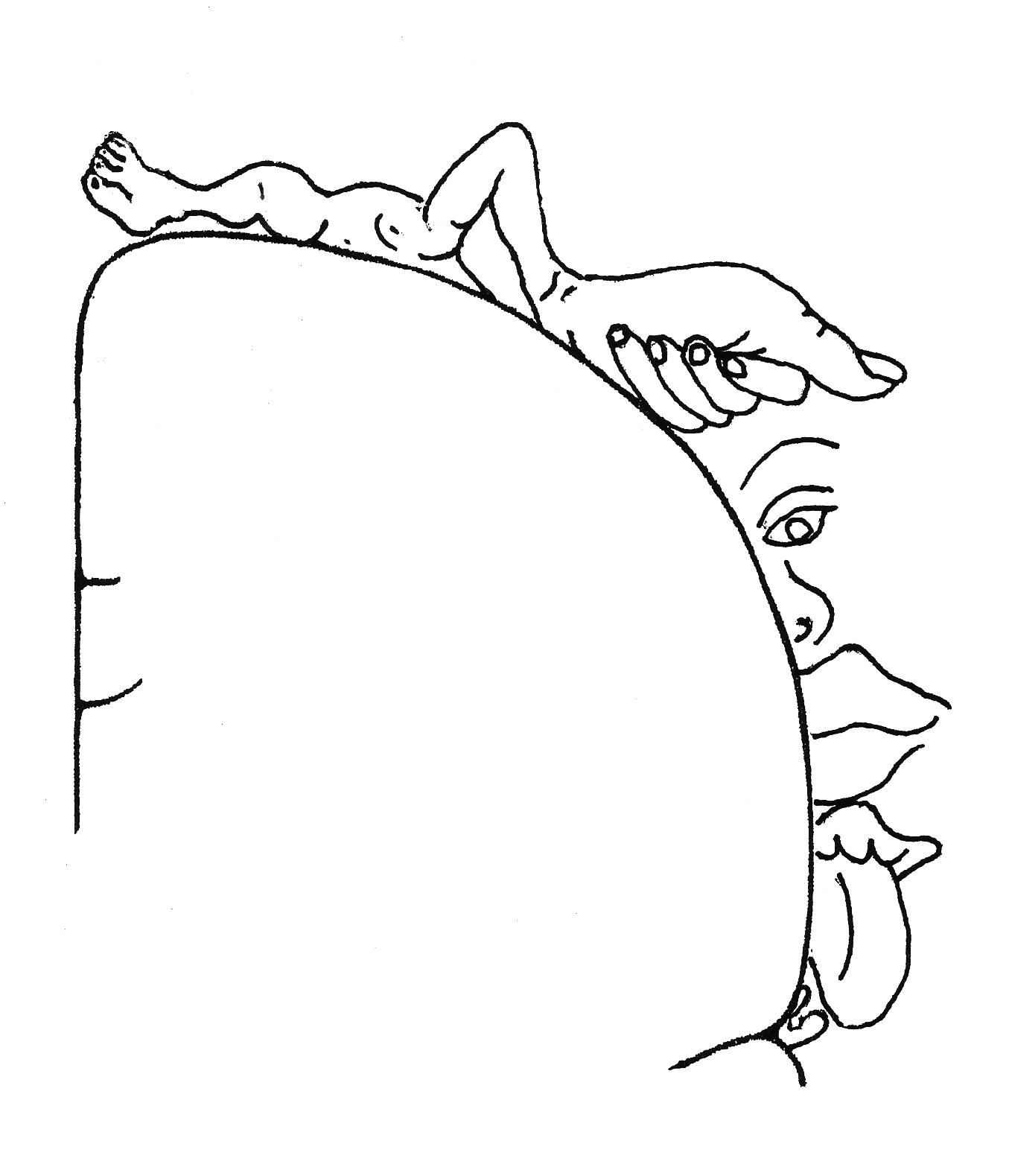
Your somatosensory system works like a home security system.

****This process is very analogous to what goes on in a human sensing situation. Take, for example, the neural mechanisms responsible for the physical sensations one experiences when shaking hands. There are touch receptors in your fingers and palm that act as the sensing devices (the contact sensor, from the alarm example). When your hand makes contact, those receptors are activated, and action potentials are fired down the attached nerve fibers to specific parts of the spinal cord where those nerves are synapsed (i.e. the relay that the cells are hard-wired to). From there, the signal travels up the spinal cord (more wired connections) and synapses with specific parts of the brain in the neocortex (the computer processor) that are specifically attuned to tactile information from the fingers and palm. Once the brain computer processes this tactile information, it can decide how to react (e.g. maintain grip, tighten it, let go, etc.) based upon if you like the person or want to impress them.

**Somatosensory cortex**

You have learned about action potentials and synapses in Labs One, Two and Three, so you should already be familiar with the way that the signal travels along the nerves and spinal cord that connect the sensory devices to the brain. Thus, the key new information here is the way that these sensory pathways are hard wired through the spinal cord and the brain. The sensory neurons that convey information from the skin, muscles and joints have their cell bodies (i.e. the nuclei, the “brains” of the cells) clustered together in the **dorsal root ganglia** (DRG). The DRG are ball-shaped neural masses comprised of thousands of cell bodies, and are found directly next to the spinal cord along its length, inside the vertebral column. From the DRG, the sensory cells synapse directly onto the spinal cord. The spinal cord is made up of **gray matter** (more cell bodies) and **white matter** (fibers); the gray matter containing sensory nuclei is grouped into what is called the **dorsal horn**, while the white matter surrounding it is divided into columns containing bundles of axons that carry the sensory information up the spinal cord.

The central axons of the dorsal root ganglion cells form a neural “map” of the body surface when they terminate onto the spinal cord. This ordered arrangement of inputs from different parts of the body surface, called **somatotopy**, is maintained through the entire somatosensory pathway up to the brain. The sensory information enters the brain in a region called the **thalamus**, essentially the gatekeeper for information to the cerebral cortex. Axons from the thalamus project to the neocortex and terminate in the **primary somatosensory cortex**. All portions of the body are represented in the cortex, in proportion to how many sensory nerves cover an area. A to-scale map for how much cortex area is dedicated to each body region is called a **homunculus**. There are more sensory nerves in the face, for example, than in the body trunk…so even though the trunk has a much larger physical mass than the face, the face portion of the somatosensory cortex is larger than that of the trunk portion.



What we’ve described here just hits the tip of the iceberg for how somatic information is processed in a person. In the body every connection between the peripheral touch receptors and the brain performs a bit of information processing, modifying the way that the info is packaged such that it increases the computational capacity of the brain. Also, each type of somatic sensation (e.g. touch, pain, position) is processed through different pathways that end in different brain regions. And sometimes the response to a sensation is hard-wired in such a way that the body responds before the signal even reaches the brain. Think of how quickly your body reacts to a painful sensation, such as putting your hand on a hot stove…your hand jerks backwards before you even necessarily realize what you’ve done, by reflex. These reflexes are governed at the level of the spinal cord to ensure quicker reactions without having to wait for the brain to decide anything.

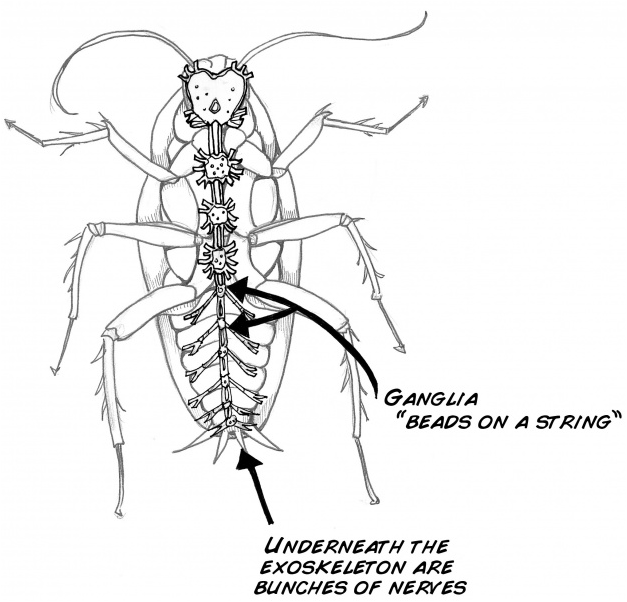
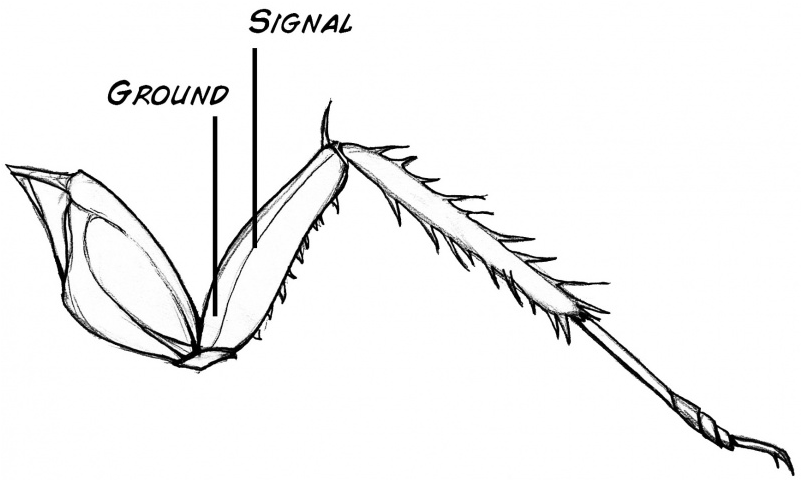
**Sensory homunculus** Map by Dr. Walter Penfield (Wikipedia.org)

But we can explore that type of complexity in another lab, on another day. The cockroach sensory system is actually a bit simpler than the human version described, with fewer nerves and connections. In the cockroach, the sensory barbs on the legs connect with the ganglia found along the midline of the cockroach (analogous to the human spinal cord). For today, let’s use our cockroach models to take a closer look at some basic relationships between sensory receptors and the internal information map that they provide to the organism.

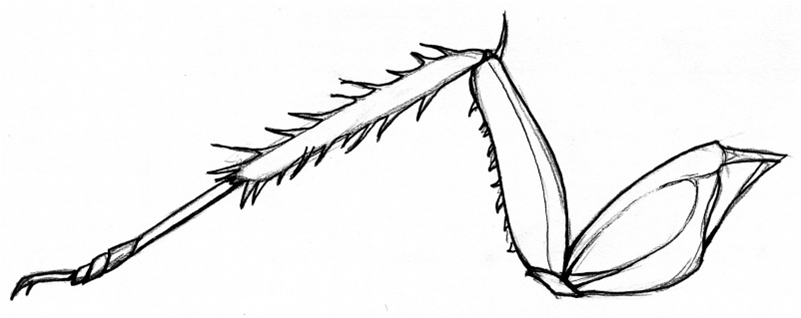
**PROCEDURE**

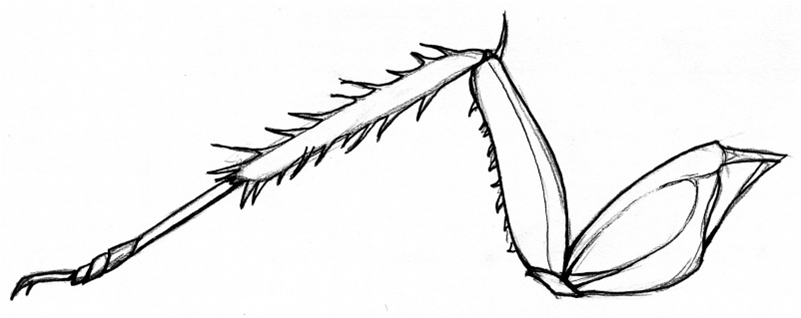
**Exercise 1: Record responses to stimulating motion-sensitive barbs**

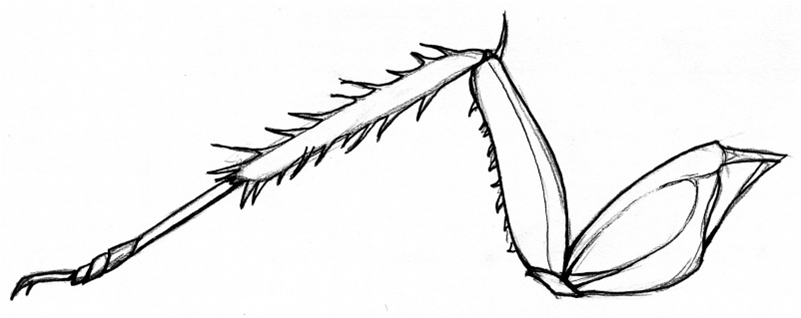
1. Plug in your smartphone or set up your computer with Audacity as previously described in experiment 1, and prepare a cockroach leg as also described in experiment 1.
2. Place both the ground and signal electrodes into the femur, as shown

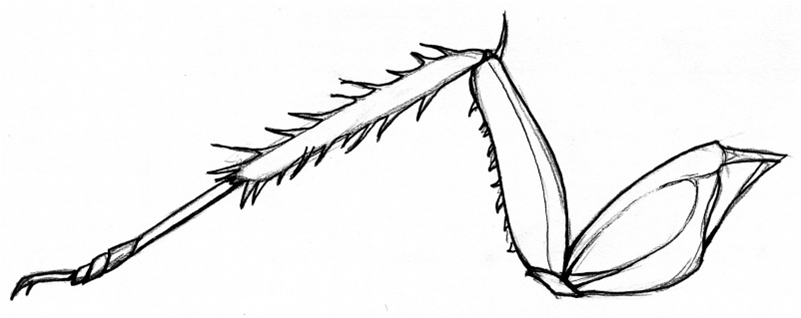


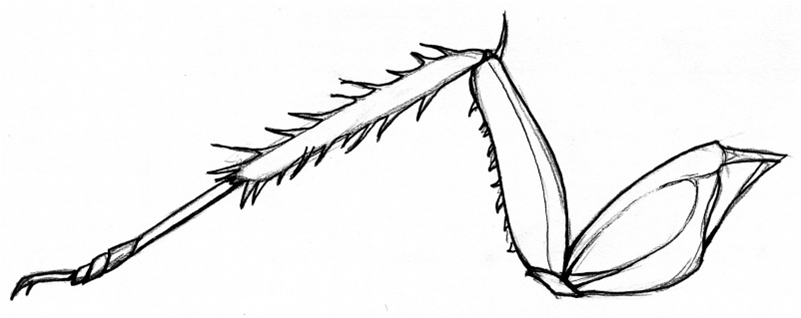
1. The leg is covered with about 20 barbs that are sensitive to motion. Using a fine-tipped toothpick, try to touch each barb as you are listening to the spikes.
2. Try to find a barb that, when touched with a toothpick, causes vigorous changes in the spiking activity. Circle the responsive barb on the diagram and draw the general location of your recording electrode as well. Note the general firing characteristics (firing frequency, relative auditory volume of spikes, etc.) of the responsive barb in your notes.
3. Repeat for different legs on your cockroach, and for multiple cockroaches.

****

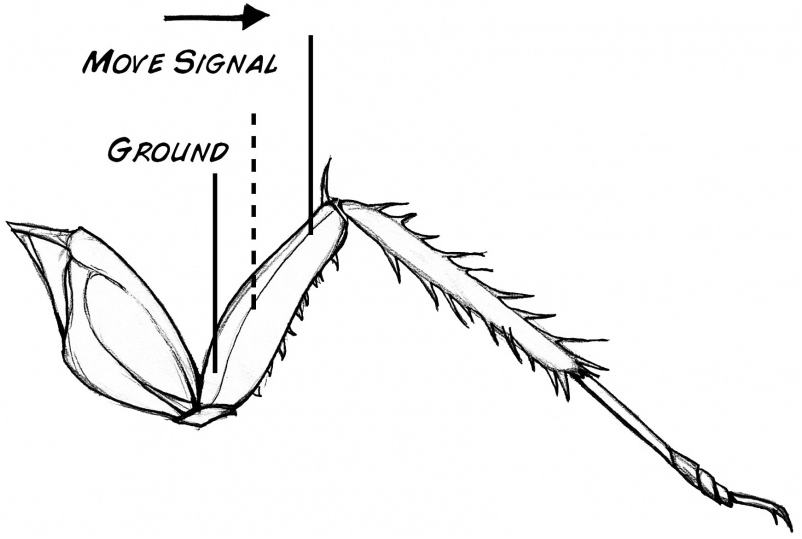
**Extra diagrams of cockroach legs to mark the activating barb and electrode location. Make copies as needed.**

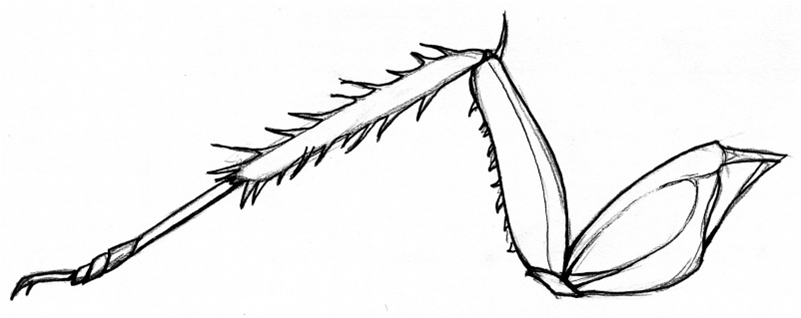
****

****

****

**Exercise 2: Move recording electrode and re-map**

1. Move the recording electrode to a different place in the femur.****
2. Repeat steps (3) and (4) from Exercise 1 to identify a responsive barb, if possible.

****

1. Repeat at least 3 times within a given leg, and repeat the entirety of both exercises on at least 3 different legs. Note: you might observe different firing characteristics based on placement.
2. From your notes and diagrams, try to create a general “map” of the relationship between which barb was responsive and the location of your recording electrode.

**DISCUSSION QUESTIONS**

1. Did you observe differences in the barb/recording location relationship from one leg to another on the same cockroach? How about legs from different cockroaches? What do your answers suggest about peripheral nerve mapping in the cockroach?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. Did the quality of your neural responses change in a negative way as you moved the recording electrode around within a single leg? If so, what might be causing the signal degradation? Do you think this will affect your observation of somatotopy?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. If instead of recording from the femur, you instead recorded further “up the path” of the nervous system in the cockroach ganglia, would you expect the cell firing patterns to be the same or different? Why?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**FUTURE EXPERIMENTS**

The third discussion question actually makes a good foundation for future experiments: repeat this exact experiment, but with the recording electrode in one of the ganglia in the body of the cockroach as opposed to in the tibia. If you are able to find a ganglion and record neural information, test how the neural firing changes as you move from one barb to another. At the end, compare the behavior of different ganglia with the behavior of the tibial nerves.